

**MAPPING
AND
AERIAL
PHOTOGRAMMETRY**

UTAH DEPARTMENT OF TRANSPORTATION

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MAPPING AND AERIAL PHOTOGRAMMETRY

STANDARD SPECIFICATIONS

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GENERAL SPECIFICATIONS

To assure a quality mapping product, good quality control procedures shall be designed and followed. Overall quality control is the responsibility of the Mapping Consultant, and is exercised at specific stages of the map production process. The State's role during data acquisition and map/database compilation will be generally limited to that of reviewing to insure that quality control checks have been completed. The mapping consultant shall be responsible for all quality control and quality assurance on the project. The magnitude of the quality control and quality assurance must be economically commensurate with the engineering project.

Process quality control is the responsibility of the consultant. This includes consultant reviews of ground control surveys, flight alignments, photographic quality, stereo compilation, map accuracy, and map completeness. The degree of quality control required by the consultant will be governed by the contract specifications and will be developed based on the end functional use of the map product. On projects involving utility relocations, property taking, and rehabilitation of existing roadways, edits (field checks) are critical. For projects involving total reconstruction in rural areas the edits may not be as extensive.

Product quality assurance also is the responsibility of the Consultant. The quality will be assured by the Consultant using a variety of inspection and testing techniques on the final deliverables. The Consultant may use third party Consultants for assurance. Prior approval of third party Consultant (Consultant and process) assurance are requirements of the State.

The State may require copies of photographs prior to the Consultant beginning to triangulate or to compile. The State may also require field survey data, printout of the aero triangulation adjustment prior to continuation. Phase delivery and inspection of a percentage of the mapping or other products before authorizing the remainder. However this phase process shall only occur on large and critical mapping projects.

The Consultant will be responsible for internal quality control functions involved with field surveying, photography and laboratory processing, stereo compilation, drafting, field checking and editing of the photogrammetrically made measurements and compiled data and maps to ascertain their completeness and accuracy. Also, the Consultant will make the additions and corrections that are required to complete the maps and photogrammetrically made measurements.

The mapping Consultant is responsible for assuring, through quality control efforts, that the deliverables meet the required accuracy and content specifications. The State may perform quality control checks as necessary to verify the quality of maps by final inspection of the delivered products.

A minimum 1% of the project will be field checked. However a minimum of 5% of the data should be checked before a determination is made that a map fails to meet specifications. The State shall determine the location of checks from preliminary completed maps provided by the Consultant. The Consultant shall perform field checks and provide documentation.

All employees of the consultant shall conduct all activities in conformance with all Federal, State, and local laws.

During the course of the work, every effort shall be made to safeguard all endangered species and to avoid the harming of any vegetation, the disruption of wildlife activities, and the damaging of items of historic or archeological interest. No historic or archaeological artifacts shall be removed by consultants personnel.

MAPPING CONTROL

A. MAP CONTROL SURVEYS

1. Topographic Map Control shall include both horizontal and vertical data and consist of ascertaining the descriptive data about, and finding on the ground, the existing basic control triangulation stations, traverse stations, bench marks, and other necessary survey points; the reconnaissance necessary to properly locate the required new traverse stations, bench marks, and other necessary survey points; the construction of the required new traverse stations, new bench marks, and other survey points; the making of the ground surveys to determine the horizontal positions of the new horizontal control stations and other necessary survey points and to determine the vertical positions of new bench marks and other necessary survey points; the taking and proper computations to adjust all position data for closure and to place all horizontal values on an adjusted ground level datum.

- a. Horizontal Control

Unless otherwise authorized, or directed, all Horizontal Control Surveys shall be made by the Traverse Method and performed in accordance with these specifications. All Traverse Surveys shall be accurately adjusted for closure by either the Compass Rule or the Method of Least Squares. Should the allowable closure error be exceeded, the angle and distance measurements shall be sufficiently strengthened so that the specified accuracies are fully met. The initial and final stations of each traverse shall be an existing station recognized as first or second order by the National Geodetic Survey. Both the initial and final stations shall be verified for position by observing azimuths to two first or second order stations and measuring the distance to one of the stations. The description and a photograph of each station shall be furnished to the Utah Department of Transportation.

- b. Horizontal Datum

North American Datum of 1983 (NAD 83) in meters shall be used for all mapping projects except when directed to match or extend existing surveys extended on the North American datum of 1927 (NAD 27). Unless otherwise specified, all mapping shall be placed on a ground datum.

Utah Statutes define the State Plane Coordinates System for the State of Utah based on the NAD 83 Coordinate System.

Horizontal Control Survey shall meet Geodetic **Third Order Class II (See Surveying by Francis H. Moffitt and John D. Bossler, 10th Edition, Page332-333).**

c. Vertical Control

All vertical control surveys shall be made by the method of differential levels. Vertical positions shall be established on all horizontal control stations and shall be considered Bench Marks. Additional Bench Marks shall be established along the traverse route so that the Bench Mark spacing shall not exceed 400 meters. All bench marks shall be so positioned that they will not be removed by future construction and shall be readily accessibly. Bench Mark Level Lines shall originate on an existing Bench Mark and terminate on an existing Bench Mark agreeing with the limits of these specifications. The originating and terminal Bench Marks must be recognized as First or Second Order by the National Geodetic Survey or the Utah Department of Transportation. The error in closure of unadjusted Bench Mark level data shall not exceed Geodetic Third Order Classification **(See Surveying by Francis H. Moffitt and John D. Bossler, 10th Edition, Page 106-107).**

d. Supplemental Horizontal Control

All existing right-of-way monuments found which describe the existing highway right-of- way shall either be included in the main horizontal control traverse scheme or sub-tied in a manner meeting the accuracy specification.

When directed, a Cadastral Survey shall be conducted at the same time as the Basic Control Survey, and shall be of the same accuracy **for horizontal and vertical control as shown above. All existing section corners and quarter corners each side of the alignment sufficient to properly compute the center of the sections, 1/16 corners etc. for the proper breakdown of the section. All existing local city and county survey monuments within 1000 meters each side of the alignment (or as determined by the Region Right of Way Engineer) which will affect the location of property boundaries for the highway right of way, shall be field located.** The survey may consist of short loop traverses originating and closing on the basic control survey points. Lost or obliterated corners shall be noted. Field notes for Cadastral survey shall be kept in a separate field book. The Consultant shall provide a photograph of all Section, 1/4 section corners found and field tied.

All existing railroads which cross the highway will be field tied both horizontally and vertically at 15 meter intervals on each track for a minimum distance of 100 meters each side of the highway control line.

All manholes for sanitary sewers, drop inlets for storm drains shall be field tied both horizontally and vertically. In all projects for reconstruction or rehabilitation, lip of curb and gutter will be field located at 15 meter intervals, inlet and outlet of drainage structures will be field located, centerline of existing roadway if not bounded by curb and gutter will be field located at 15 meter intervals, multi lane freeways will have shoulders of each roadway and ramp field located on 15 meter intervals. All existing signs and above ground utilities will also be field located, including water valves boxes, gas valve boxes and any other features or markers significant to a highway project. Location as indicated shall include vertical and horizontal measurements.

A survey report shall be supplied to UDOT, which shall include a discussion of control used, measurements completed, computations made, and accuracies attained. The report shall include tabulations of coordinates computed before any corrections and adjustments were applied to the data as well as for each intermediate step up to and including the final coordinates. The survey report shall include a diagram on a minimum scale of 1:24000, preferably on a geological survey or other acceptable reproducible map showing the position of all points surveyed: Section Corners, Quarter Corners, Control Monuments used, Control Monuments set. The (x,y,z) coordinates shall be noted on map. The survey report shall be accompanied by all field notebooks used in the survey or printouts or electronically recorded field notes. The map shall show accuracy of survey and a certification number and signature of the licensed surveyor who supervised the field survey. Copies of the report and map shall be delivered to the Project Manager and the Central Records Documents Manager.

e. Monuments:

A monument may serve as both a vertical and horizontal marker. All monuments required for basic control and azimuth marks, shall be placed before the point is occupied.

Basic control monuments including azimuth markers shall be permanent markers. A marker shall be placed at each end of the project with additional markers set at 800 meter increments. All other monuments to remain in place shall be semi- permanent. All monuments shall be marked with a 2.5 meter metal fence post, if conditions permit.

f. Clean-Up

Upon acceptance of the mapping, the Consultant shall be responsible to pick up all material used for survey, targets, panels, ribbon, and additional material and dispose of it in a proper disposal area.

B. FIELD NOTES, SKETCHES AND OFFICE BINDER

All original field notes and sketches shall become a permanent record of the State of Utah. Therefore, paper size and format must conform with practices of the recording and filing systems currently in use. The project designation, nature of the notes in the book and the name of the surveyor shall be clearly identified on cover and on the first page of the book. Each book shall be fully indexed. There shall be drawings to aid in the interpretation of angle points, control monuments and section corners and quarter corners. There shall be no erasures; rejected readings or errors shall have a line drawn through them with the replacement or corrected data written beside or above the original entry. When the project is completed all original notebooks shall become the property of the UDOT.

1. Paper

The paper used for recording field data shall be 4 5/8 X 7 1/4 six-hole loose leaves punched at 3/4" and 3/4" intervals. K&E 82 0287 ruled leaves, or their equal, shall be used for level notes. K&E 81 0275 mining leaves, with a 10 X 10 grid on the face and a ruled back, Dietzgen 384-3 Engineer leaves, with a 4 X 8 grid face and a ruled back, or either sequal may be used for recording theodolite data, chained measurements and other activity information requiring sketches.

Preprinted forms for recording Electronic Distance data will be furnished by the Consultant for prior approval by the Utah Department of Transportation.

2. Recording

When Mining or Engineer leaves are used, data will be recorded with the ruled side of the sheet on the left-hand side of the rings and the grid side of the sheet on the right. With either type sheet, data shall be recorded on only one side of each sheet. A blank ruled side and a blank grid side will then occur between each two sheets containing recorded data.

When using leaves that are ruled on both sides, level data shall be entered on every left- hand side sheet and descriptions or supplemental data entered in the right-hand sheet with both sides of the sheet being used.

3. Office Binders

a. Field Notes

The binder(s) to combine the field notes in their submission form shall be K&E 82 0540, or equal, with 3 3/4" ring spacing. Each binder submitted will be complete. The contents shall contain the following and the arrangement shall be as follows:

Title Page
Party and Book Index Page
Index
Field Notes

b. Job Abstract Binder Number 1 of a set shall contain the total for:

Horizontal Angles
Vertical Angles
Distances
Elevations

c. Reference to Binder Number and Page is entered in the abstract. All the information required for computation and plotting will be contained in Binder Number 1.

d. Following the abstract, Binder Number 1 shall contain the original field data sheets used for recording the angles, elevations, distances, etc. Notes for each type of work shall be grouped together.

e. Supplemental data obtained at a later date for a job should be entered in the back of the last office binder. In Binder Number 1, under Index of Binders, make an entry for the supplemental data. This data is to be complete, with index and abstracts.

Recovery Notes, Descriptions, Etc., shall be submitted on the prescribed preprinted forms and shall be included, properly numbered, as the last pages in the last binder. Should the number of forms exceed 50 when assembling the contents, no more than 125 pages, (250 sheets) should be included in any one Office Binder.

4. Turn in Package

All surveying, consulting engineer, consulting surveyor, and aerial mapping firms providing topographic mapping services either by contract or subcontract with the Utah Department of Transportation shall, at the completion of the topographic map control survey, submit a turn-in package to the Project Manager which shall contain the following items:

- a. Copies of the original field survey data as recorded.
- b. Copies of the descriptions for all existing and established horizontal survey stations, bench marks, section and quarter corners, and other significant points including the control survey.
- c. Copies of the computations adjusting the leveling data and the reduction to the Mean Sea Level Datum.
- d. Copies of the computations adjusting the horizontal control for closure and for the placing of map control positions on the Adjusted Grid System.

5. Electronic Survey Systems

Parts 3B, 3C, 3D, and 3E do not apply when survey data is gathered through the use of Total Survey Stations and Electronic Data Collectors.

In-lieu-of, survey data shall be submitted as follows:

- a. A print out of Raw Field Data.
- b. A printout of all data reduction computations including Control point computations (X, Y, Z), Azimuth closure and position closure
- c. A printout of adjusted Coordinates (X, Y, Z).
- d. All of the above data in ASCII Format on an electronic media acceptable to the Project Manager.
- e. Copies of Recovery Notes and Descriptions.

GLOBAL POSITIONING TECHNIQUES

A. DESCRIPTION

1. General

This specification covers a three-dimensional measurement system based on observation of the radio signals of the NAVASTAR GLOBAL POSITIONING SYSTEM (GPS).

2. Definitions

For the purpose of these specifications, the following definitions apply:

N.G.S.: National Geodetic Survey

Geodetic Survey: First or second-order survey which is intended for possible submission to N.G.S. for assimilation into their data base.

3. Instruments and Procedures

All work must be accomplished using instruments and following procedures acceptable to the Project Manager.

All work must be accomplished using instruments and following procedures acceptable to the National Geodetic Survey. The General Accuracy Standards will be as provided under Section 2, METHODS AND PROCEDURES,

4. Turn in Package

The Turn-in Package shall be totally complete and acceptable to the Project Manager. The requirements of the package shall be such that the Utah Department of Transportation may submit the data to the National Geodetic Survey without further treatment.

B. METHODS AND PROCEDURES

1. General

Unless otherwise specified under Special Provisions, directed, or authorized, all methods and procedures employed by the Consultant shall conform to those presented by the National Geodetic Survey in their most recent revision of the document entitled PROPOSED GEOMETRIC GEODETIC SURVEY STANDARDS AND SPECIFICATIONS FOR GEODETIC SURVEYS USING RELATIVE POSITIONING GPS TECHNIQUES. The accuracy standards for Geometric Relative Position and Orthometric Height Difference will be determined for each project site by the Consultant.

2. Schedules of Operations

The Consultant shall develop an operation schedule prior to beginning the work. A copy shall be provided to the Project Manager for approval with respect to stations field located within the traveled way of thoroughfares having high traffic volumes, the Consultant shall, wherever possible schedule monumentations and observations to minimize conflicts with traffic.

3. All instruments and equipment, necessary to perform the work, shall be in good working order and shall meet all State, Federal and local regulations applicable to the location of the work.

All instruments shall be of sufficient precision to achieve the accuracy specified for the survey. Prior to beginning the work, the Consultant shall furnish to the Project Manager, a list of all instruments to be used during the course of the project, including the name, manufacture, model and year-of-manufacture.

4. Completion of Field Work

Before the GPS team departs the project area, all project data shall be reviewed and assessed for accuracy and completeness. Should the results not meet the specifications, additional observing sessions shall be conducted until the minimum requirements are satisfied. All data processing shall be coordinated with the Project Manager.

C. EQUIPMENT TESTING

1. Extent

All receivers, to be included in the survey, shall be tested prior to their inclusion in the system. In addition, any previously tested instrument which receives modification or repairs, which affect the observation results, shall be retested before again being included in the system.

D. MINIMUM FIELD DATA REQUIREMENTS

1. Recorded Data

For each observation station, sufficient data shall be recorded to develop the following position values:

The horizontal position (N,E) stated in values of the Utah State Plane Coordinate System for the zone specified in the project description. The horizontal position shall be referenced to the NAD 83 coordinate system in meters unless otherwise specified.

The geoid height difference, the ellipsoid height difference, and the computed station elevation shall be referenced to the 1988 North American Sea Level Datum or other datum specified in the project description.

All control positions set shall have been computed by a minimum of four (4) triangles, to verify global positioning.

AERIAL PHOTOGRAPHY

A. GENERAL

1. The intent of the specifications, and proposal is to prescribe the details for performance and completion of the work which the consultant undertakes in accordance with the terms of the contract. Where the specifications and work task order describe portions of the work in general terms, but not in complete detail, it is understood that only materials and workmanship of the first quality are to be used. The consultant shall furnish all labor, materials, tools, equipment, and incidentals, and do all the work involved in executing the contract.
2. The Consultant shall have previous experience in the type of specialized aerial photography and laboratory work required in these specifications. The Consultant shall own or have available for use:
 - a. A suitable airplane capable of a 20,000 foot operational altitude. The statement shall include the names of the pilot and photographer.
 - b. A 153 mm nominal focal length precision cartographic camera with an acceptable calibration report.
 - c. A flight log representing aircraft flight time shall be maintained on an hourly basis to the nearest 0.1 of an hour between the time of takeoff and the time of landing for the contract. The log shall be signed by the pilot or the aerial photographer and be submitted with each contract.
 - d. The consultant shall maintain an aviation weather log consisting of the following:
 - C Date of weather data.
 - C Photography location and identification.
 - C Documented weather forecast for photography location area.The weather log shall be included with copies of aerial photography.
3. Aerial photographs shall be taken between the hours of 10:00 am and 2:00 PM local solar time, on days when well defined images can be obtained. Photographing shall not be attempted when the ground is obscured by haze, smoke or dust, snow or when clouds or cloud shadows will appear on more than five percent of the area of any one photograph. Photographs shall not contain shadows caused by topographic relief or sun angle, whenever such shadows can be avoided during the time of year the photography must be taken.

4. Ground conditions: The season and any special requirements concerning foliage, snow, or other conditions which might obscure ground detail may limit the seasons that photography may be taken. It shall be the responsibility of the consultant to schedule photography to avoid these conditions. However, if questions or concerns as to conditions exist, consultation with the project manager shall occur before undertaking or continuing the photographic operations.
5. The aircraft furnished shall be capable of stable performance shall be equipped with essential navigation and photographic instruments and accessories, with all maintained in operational condition during the photographic mission. No windows shall be interposed between the camera lens system and the terrain. Also, the camera lens system shall not be in the direct path of any exhaust gases or oil from aircraft engines.
6. Flight height: Departures from the specified flight height shall not exceed 2 percent low or 5 percent high for all flight heights up to 2,000 feet above ground elevation. Above 12,000 feet, departures from specified flight height shall not exceed 2 percent low or 600 feet higher .

Inspection for Flight Height: During inspection for acceptance, the flight height will be verified by multiplying the focal length of the camera (in feet) by the denominator of the calculated scale for the aerial film. The photography scale is calculated by dividing the distance between two identifiable points as measured on one of the photographs (as near as possible at the mean ground elevation) by the actual ground distance as measured from the best available map.

7. Flight line Maps: The flight line maps shall be prepared by the consultant. The maps will be current (up to date) standard topographic maps and of the largest scale compatible with the project scale. The project boundaries shall be clearly marked. The flight line map shall be reviewed by the project manager.
 - a. The flight height above the average elevation of the ground shall be such that the negatives have an average scale suitable for attaining the required photogrammetric measurement, map scale, contour interval and accuracy.

Negatives having a departure from the specified scale of more than five percent because of tilt or any changes in the flying height shall be rejected.

- b. All of the area appearing on the first and last negative of each flight line that crosses a project boundary shall be outside the boundary. Each strip of photographs along a project boundary shall extend over the boundary not less than 15 percent.

- c. End lap (overlap in the line of flight shall not exceed 65% nor be less than 55%, and shall average 60% plus or minus 2%. Sidelap (overlap of parallel strips of aerial photography) shall not exceed 40%, nor be less than 20% and shall average 30% plus or minus 5%. However, UDOT reserves the right to specify end lap and/or sidelap for individual projects.
- d. Terrain Elevation Variances. When ground heights within the area of overlap vary by more than ten percent of the flying height a reasonable variation in the stated overlaps shall be permitted provided that the fore and aft overlap does not fall below fifty-five percent and the lateral side lap does not fall below ten percent or exceed twenty percent. In extreme terrain relief where the foregoing overlap conditions are impossible to maintain in straight and parallel flight lines, the gaps created by excessive relief shall be filled by short strips flown between the main flight lines and parallel to them.
- e. Crab. Any series of two or more consecutive photographs crabbed in excess of ten degrees as measured from the mean flight path of the airplane, as indicated by the principal points of the consecutive photographs, may be considered cause for rejection of the photographs. Average crab for any flight line shall not exceed five degrees. Relative crab in excess of ten degrees between two successive exposures shall be rejected. For aero triangulation, no photograph shall be crabbed in excess of five degrees as measured from the line of flight.
- f. Tilt. Negatives exposed with the optical axis of the aerial camera in a vertical position are desired. Tilt (angular departure of the aerial camera axis from a vertical line at the instant of exposure) in any negative of more than three degrees an average tilt of more than one degree for the entire project, an average of more than two degrees for any ten consecutive frames, or relative tilt between any two successive negatives exceeding five degrees, shall be cause for rejection.
- g. UDOT reserves the right to order the consultant to make reflights at his own expense whenever the aerial photography is rejected for failure to meet specifications.
- h. The selection of an appropriate contour interval is extremely site-dependent and will be indicated in the work task order or RFP. All UDOT mapping will be class I unless otherwise noted. The following table may be used to determine flight height.

Negative Scale for Topographic Development		
	1200 C-Factor	1500 C-Factor
.2m Contour	1" = 133' (1:1600)	1" = 167' (1:2000)
.5m Contour	1" = 333' (1:4000)	1" = 417' (1:5000)
1m Contour	1" = 667' (1:8000)	1" = 833' (1:10000)

B. AERIAL CAMERAS

The photographs to be used in precise photogrammetric work must be obtained through the use of a fully calibrated precision camera with a single high resolution low distortion lens. Cameras used for photogrammetric mapping must meet the requirements outlined below. The aerial camera used shall be equipped with forward motion compensation.

The camera shall have been calibrated by the U.S.Geological Survey, within the past 3 years.

1. Type of Camera: A single lens precise aerial mapping camera equipped with a high resolution, distortion free lens shall be used. The camera shall function properly at the necessary altitude and under expected climatic conditions, and shall expose a 9-inch square negative. The lens cone shall be so constructed that the lens, focal plane at calibrated focal length, fiducial markers and marginal data markers comprise an integral unit or are otherwise fixed in rigid orientation with one another. Dimensional changes brought about by variations of temperature or other conditions shall not be of such magnitude as would cause deviation from the calibration focal length in excess of plus or minus 0.05 millimeter or would preclude a determination of the point of location to within plus or minus 0.003 millimeters.

The calibration report shall be presented to the consultant manager prior to award. Certification shall also be provided indicating that preventative maintenance has been performed within the last two years. The camera features shall be as follows:

The calibrated focal length of the lens shall be 153 millimeters, plus or minus 3 millimeters, and measured to nearest .001 millimeter.

The focal plane surface of the platen shall be flat to within 0.013 millimeters and shall be truly normal to the optical axis of the lens. The camera shall be equipped with means of holding the film motionless and flat against the platen at the instant of exposure

The camera shall be equipped with a minimum of four fiducial marks, with eight preferably for accurately locating the principal point of the photograph. The lines joining opposite pairs of fiducial marks shall intersect at an angle within one minute of 90 degrees.

The absolute value of radial distortion measured at maximum aperture, as stated in the calibration report, shall not exceed 0.01 millimeter. The tangential distortion shall not exceed 0.005 millimeters.

With appropriate filter mounted in place, the Area Weighted Average Resolution shall be at least sixty lines/millimeter when measured on type V-F spectroscopic plates at maximum aperture stated on calibration report. The lens shall be fully corrected for color photography.

An appropriate light filter with an antivignetting metallic coating shall be used. The two surfaces of the filter shall be parallel to within ten seconds of arc. The optical characteristics of the filter shall be such that its addition and use shall not cause any undesirable reduction in image resolution and shall not harmfully alter the optical characteristics of the camera lens.

The camera shall be equipped with a between-the-lens shutter of the variable speed type, whose efficiency shall be at least eighty percent at the fastest rated speed.

The deviation from flatness of the average data from two models (elevation discrepancy at photography scale) at measured points may not exceed plus or minus 1/8000 of the focal length of a nominal 6-inch (153 mm) focal length camera. If elevation discrepancies exceed this value, the camera will not be acceptable.

C. PHOTOGRAPHIC FILM

Only unexpired film of the type specified shall be used. All film shall be purchased by the consultant. All aerial film shall be of archival quality. The film exposed and processed shall not be spliced. The processed negatives shall be free of stains, discoloration, or brittleness that can be attributed to ageing.

1. TYPES OF AERIAL FILM.

The Consultant shall furnish aerial film of a quality that is equal to or superior to 4 mil Kodak Double-X Aerographic 2405 (Estar Base) panchromatic film; 4 mil Kodak Plus Aerographic 2402 panchromatic (Estar Base) film; 4 mil Kodak Infrared Aerographic 2424 film; 4 mil Kodak Aerochrome Infrared 2443 film (estar Base). Only fresh, fine grain, dimensionally stable, and safety base aerial film shall be used.

Color infrared (CIR) emulsion shall be sensitive to the visible and near infrared spectrum from 400 to 900 nanometers. The film shall be a polyester base with a nominal thickness of 0.8 mils and shall have three gelatine layers containing silver halide, one layer to be sensitive to infrared light, one to be sensitive to green light, and the other to be sensitive to red light.

Black-and white emulsion shall be sensitive to red, green, and blue wave lengths.

All aerial film shall be processed under controlled conditions in automatic, continuous-film processors. The film shall be processed in accordance with the manufacturer's instruction. The processing, including development and fixation, and washing and drying of all exposed photographic film, shall result in negatives free from chemical or other stains, containing normal and uniform density, and fine-grain quality. Before, during and after processing, the film shall not be rolled tightly on drums or in any way stretched, distorted, scratched, or marked, and shall be free from finger marks, dirt, or blemishes of any kind.

PHOTOGRAMMETRIC MAPPING

A. GENERAL

The work to be done consists of furnishing topographic maps, with a specified contour interval supplemented with spot elevations, at a specified scale, as described in the work task order or RFP. The work to be done will require the Consultant to furnish the topographic field control data, aerial photography and materials necessary for finishing the topographic maps.

B. CONTOUR AND PLANIMETRIC MAPS

1. PLOTTERS

The work to be done will be planned for a precision stereoscopic plotter. The type of stereoscopic plotter instruments and any interfaced plotting equipment (such as automatic plotting tables or CADD related, in line, hardware) that will be used by the consultant is to be submitted to UDOT for approval before award of the Contract to the Consultant.

The photo scales and the attendant map scale (compilation scale) to be used by the Consultant shall be submitted to UDOT for Approval before award of the Contract to the Consultant.

The “c” factors to be used by the Consultant for “softcopy” work stations shall not exceed 1200. The “c” factors to be used by the consultant for second order optical train and first order analytical instruments shall not exceed 1500.

2. DATUM

The North American Datum of 1983 (NAD 83) in meters will be used for all mapping projects except when matching or extending existing mapping based on North American Datum of 1927 (NAD 27). Unless specified, all mapping shall be placed on a ground datum utilizing State Plane Coordinate Grid Adjustment Factors.

The final map shall show all grid ticks as well as horizontal and vertical control. It shall be the responsibility of the Consultant to document control in conformance with these specifications.

The maps shall be compiled at the scale and contour interval specified in the work task order or RFP.

The mapping limits and the numbering, dimensions, and orientation of the final maps shall be as specified in work task order, RFP, or as directed by consultant manager.

Adjacent map files shall butt match exactly. Match lines shall be delineated and labeled as prescribed in the UDOT "CADD Standards".

Where the meaning of symbols is obscured by adjacent topography, the object shall be labeled.

Where the symbols shown do not properly describe a planimetric feature, the Consultant shall select an appropriate symbol and label the feature.

Labels shall be oriented along linear features or parallel to the flight line of the stereo model being compiled, so that project beginning shall be at the left and project end shall be at the right

3. DIGITAL PHOTOGRAMMETRIC STEREO COMPILATION

In order that the maps be compatible with the UDOT CADD System, the following requirements must be met:

- a. Maps produced on a CADD system by the Consultant shall conform to UDOT's current CADD standards. This includes levels, line codes, line weights, line color, symbols, and text.
- b. The data files provided by the Consultant shall be intergraph vector files which can be manipulated with standard Intergraph IGDS software. Raster image files and all other file formats (such as DXF or SIF) are not acceptable.
- c. All files provided by the Consultant shall be delivered on Industry-Standard MS-Dos compliant data compact Disk (CD-Rom), approximately 640mb capacity or greater.
- d. Use of reference files or pen tables to achieve particular plotted effects is not allowed, each file must stand on its own.
- e. Each file shall contain map features for one or more stereo models. Individual stereo models shall not be separated into more than one file regardless of size. Files shall be merged so as to contain approximately 1500 blocks but should be limited in size not to exceed 72" in length when plotted at final map scale.

- f. The name of the design file must appear in the lower left corner of the final plotted map sheet. Each file shall be numbered using a four digit number, followed by a one letter designation for the flight line number, followed by a four digit number representing the first and last photo numbers representing the first and last photo numbers of the stereo models in the file. (Example) 2771E908.
- g. Files shall be compiled with coordinate values to the nearest thousandth (1/1000) of a meter. Coordinate values for all features shall be based on the grid system indicated by the control data. The working units for design files shall be:

Master Units 1 Meter: Sub Units = 10 (1/10 Meter): Positional Units = 100 (1/1000 meter).

The global origin shall be set such that the working units origin (0.0) shall be at the center of the design plane.
- h. All digital data shall be recorded directly as a function to the stereo plotter operation. Post compilation digitizing of graphic compilation is not acceptable. Contours shall be generated from surface point files.

4. CONTENTS OF MAPS

All map features shall be as prescribed in the UDOT "CADD Standards"

The completed maps shall show horizontal control monuments, bench marks, section corners, city street monuments, right-of-way monuments, contours, grid system, and all topographic and planimetric features shown in the "CADD Standards."

The consultant will be required to label all streets and public buildings. All important cultural topographic features shall be properly and adequately labeled on the final maps so as to be complete within one map. Published information may be used as a source for this data, and field inspection or verification will not be required.

5. MONUMENTS, BENCH MARKS AND GRID SYSTEM

Grids shall be shown with three centimeter long grid cross-ticks spaced at twenty five centimeter intervals at final map scale. Grids shall be labeled around the perimeter of the map. Grids on adjacent maps shall be a continuation of the twenty five centimeter intervals. Intermediate grid intervals shall be used when necessary to fulfill this requirement. Any such intermediate grids need not be labeled.

Grid coordinate values shall be designated Y and X.

6. TOPOGRAPHIC FEATURES

The Project Manager shall specify the required contour interval or every fourth contour shall be of heavier weight (except 0.2m contours shall be a heavier weight for every 5th contour). Care shall be exercised in labeling contours to the end that the elevation of any contour is readily discernible. Contour designations shall not be abbreviated. All digits shall be shown on the contour maps.

Labels shall be orientated to follow the contours and be readable from the same direction as other text. The distance along a contour between labels shall not exceed 25 centimeters at map scale. There shall be a break in the contour wide enough to allow placement of the contour label. Where possible, contour labels shall be in diagonal stacks one above another along the line of the slope.

All contours shall be continuous.

In areas of comparatively level terrain where contours are more than five centimeters apart at final map scale, the contours shall be supplemented by spot elevations spaced 2.5 centimeters apart at final map scale in each direction to form a rectangular grid, parallel to the center of the mapping area. In built-up areas where trees or buildings preclude exact adherence to a grid pattern, the pattern may be varied but the density and spacing of spot elevations shall not be less than that of the grid pattern.

Where the profile gradient is 2 percent or less, spot elevations shall be shown at intervals not greater than 5 centimeters at final map scale, along the center of dikes, roads, ditches, and railroads. Spot elevations shall be shown at all sags and crests regardless of gradient. The spot elevations for roads and railroads crossing highways will be field supplied.

Spot elevation shall be shown at intervals not exceeding 5 centimeters at final map scale, along the boundary of the area to be mapped at locations where the nearest contour is over 2.5 centimeters from the boundary.

Where interpolation of the contours will not show correct elevations, such as summits, depressions, saddles, and road intersections, spot elevations shall be shown.

All spot elevations shall be labeled with decimal values giving their elevation to three significant figures rounded to the nearest one-tenth of a meter. Labels shall be placed parallel to the flight line and positioned so that they do not obscure other map features.

When the digital terrain model is produced photogrammetrically, and where areas of structure, brush, or tree cover obscure the ground so that the digital terrain model cannot be measured completely and accurately from the photographs, the data necessary to complete the work shall be secured by ground surveys.

When the map is to be used for rehabilitation or reconstruction where the new pavement is to be placed immediately on top of the existing pavement, the spot elevations for center of road, curb and gutter, edge of road, and utility locations shall be obtained by field procedures as noted previously.

7. PLANIMETRIC FEATURES

All planimetric features which are visible or identifiable on, or are interpretable from the aerial photography shall be shown. Particular attention shall be given to include drainage features, fences, walls, and other indications of property lines or lines of occupation. The field data locating utilities will be used to supplement those noted from aerial photography.

The maps shall show all roads, railroads, bridges, canals, streams, dams, fence lines, wells, power and telephone poles, billboards, highway signing, and highway culverts, which are visible on the aerial photographs, or were obtained from field means. They shall also show boundaries of timber and brush areas, slide and slip out areas, orchards, vineyards, and any other improvements or distinguishing features which are visible on the aerial photographs.

Orchards planted in regular rows may be symbolized by a dot for each tree, except for the outer rows which shall be shown by appropriate symbol. Free standing trees having a crown diameter of 5 meters or more shall be shown.

All schools, parks, playgrounds, cemeteries, public buildings, hospitals, churches, institutions, and similar places of public gatherings shall be shown and labeled. Published information may be used as a source for this data and field inspection or verification will not be required.

Roadway lane striping if visible or obtained by field data shall be delineated by appropriate symbol.

Drainage lines shall be shown in all well-defined drainage features indicated by the contours where the drainage is over 150 meters in length.

Roads, streets, and sidewalks shall be shown as the separation between curb faces, hard surface edges, travel paths, or shoulder lines, as the case may be. The drafting of road alignment, shall be especially carefully executed. Roads or regular alignment shall be plotted with straightedge and regular curves. Freehand or irregular curve drawing will be permitted only on meandering roads or trails or irregular alignments.

The surface type of all roads, drainage ditches, parking areas and other improved areas, except for private residential features, shall be identified and labeled by type, i.e., asphalt, concrete, brick, dirt, etc., as interpreted from field notes or aerial photographs.

Features which are interpreted from the photography as being under construction shall be labeled as such, and partly completed planimetric features in connection therewith shall be shown by dashed lines.

Any pattern of lines visible on the photographs, but which cannot be readily identified as definite features and shown by a standard symbol, will be located and shown on the map by fine dotted lines.

8. ACCURACY OF MAPS

All map accuracies specified herein shall apply to the individual stereo models that comprise the finished maps delivered by the consultant.

The plotted position of all coordinate grid ticks and/or grid lines, and all monuments, except bench marks, shall not vary more than 0.25 mm from their calculated position.

At least 90 percent of all well defined planimetric features shall be within 0.65 mm of their true position, and 100 percent shall meet class I standards:

Planimetric (X or Y) Accuracy (Limiting rms error, meters) map scale	
0.0125	1:50
0.0250	1:100
0.0500	1:200
0.125	1:500

The width of all curbed streets, vehicular structures, traffic lanes, and highway surfaces whose edges are well-defined shall not vary more than 0.65mm from their true width. The street side of lines delineating curbs shall be the face of the curb.

At least 90 percent of all contours shall be within one-half contour interval (C.I.) of true elevation, and all contours shall be within one contour interval of true elevation, except as follows:

In densely wooded areas where the ground is obscured by dense brush or tree cover, contours shall be plotted as accurately as possible, while making maximum use of spot elevations obtained from stereoscopic model in places where the ground is visible, and/or with elevations furnished by field survey methods. In those areas where spot elevations can be obtained photogrammetrically and/or if elevations are furnished by field survey elevations are, at least 90 percent of all contours shall be within one contour interval of true elevation. Contours in such areas shall be indicated by dashed lines.

Orchards and areas devoted to crops will be considered as open areas and are therefore subject to larger tolerances in vertical accuracy.

The accuracy tolerance allowed for contours shall not affect the requirement that contours reflect the crown or cross slope of all paved areas including paved ditches.

In addition to the accuracy specified above for contours and spot elevations, the following shall apply:

The arithmetic mean of contours and spot elevations in open areas shall not exceed plus or minus the following values for the points tested on each map sheet.

No. of Points Tested	Max. Arithmetic Mean
20	0.20 C.I.
40	0.15 C.I.
60 or more	0.10 C.I.

Any contour which can be brought within the specified vertical tolerances by shifting its plotted position 0.65 mm shall be accepted as correctly plotted.